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THE GRANITE INDUSTRY
DIMENSION STONE

BY

OLIVER BOWLES

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By Oliver Bowles[2]

TABLE OF CONTENTS

Page
Occurrence and character of granite 1
Types of products 2
Uses 3
Distribution of granites in the United States 3
Desirable qualities of a deposit 4
Economic conditions 5
Quarry methods 5
Finishing methods 7
Monumental and building granites
  Monumental granites 8
  Building granites 8
Statistics of production 9
Imports and exports 9
Rates of duty 10
Prices 10

OCCURRENCE AND CHARACTER OF GRANITE

Granites are classed as igneous rocks; they have been formed by the solidification of rock magmas or solutions from deep within the earth. It is an almost invariable law of nature that magmas which cool quickly form fine-grained or glassy rocks, while those that cool slowly are completely crystallized and are coarser-grained. Granites, being of the latter class, are regarded as having attained their solid form at considerable depth below the surface under conditions of high temperature and pressure. The constituent minerals crystallized out slowly, the crystals interlocking with one another. The great depth of overlying rocks that must have been present when crystallization took place has been removed by erosion over large areas on the surface of the earth, in consequence of which granites appear at or near the surface in many localities.

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[1] - The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6268."

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The chief minerals of which granites are formed are feldspars, quartz, and either mica or hornblende. All the essential constituents except mica are as hard as, or harder than steel, therefore granites are difficult rocks to cut and dress. Granites are usually red, pink, or gray, depending on the color of the feldspars. If hornblende or black mica is abundant the rock may be dark green or almost black.

Granites are characterized by massive homogeneous texture. They are classified as fine-grained, medium-grained, or coarse-grained. Medium-grained granites are those in which the feldspar crystals average about one-fourth inch in diameter. If relatively coarse-grained crystals appear in a fine-grained ground mass the rock is designated a porphyritic granite. Uniformity in texture and grain size are desirable in building and ornamental stone, although occasionally rocks of variable texture, such as the porphyritic granites, are used. A rock may have the mineral constituents of a granite but show a banded or platy structure due to recrystallization, folding, or other changes while the rock was in a plastic or semimolten condition. Such metamorphic rocks are called granite gneisses. They are used occasionally for building purposes but not as commonly as the uniformly textured granites.

Granites are named from the most abundant mineral - other than quartz and feldspar - that they contain, being called, for example, biotite granite or hornblende granite.

Commercially other igneous rocks granitoid in texture but more properly classified as syenites, diorites, or gabbros may be classed as granites. Thus the "black granite" of Little Falls, Minn., is a diorite, and the "black granite" of Eastern Pennsylvania consists of diabase or gabbro.

The question is sometimes raised as to the depth to which a granite occurrence may extend. In this respect granites differ notably from limestones, sandstones, or other sedimentary rocks. The sediments were originally laid down in relatively thin beds, and individual formations providing rock of economic value may be quite limited in thickness. Usually the usable beds range between 40 and 200 feet in thickness. On the other hand, granite comes up from below. Its depth is unknown, but in general is very great. It may even be measurable in miles. The reserves of material at depth are to be measured, therefore, by the economic depth of working rather than by the vertical extent of the rock mass. Exceptionally, granites of commercial quality may occur in sills or sheets of limited thickness flanked on either side by rocks of different character, as, for example, at Westerly, R. I.

TYPES OF PRODUCTS

Granite quarries fall logically into two groups, those producing broken or crushed stone and those producing dimension stone. The quarries of the first group provide irregular fragments of various sizes, while the products of the second group of quarries are cut to specific sizes and shapes. The larger products of the broken stone quarries consist of riprap for railroad or highway fills, shore protection, spillways at dams, breakwaters, and similar uses where large irregular blocks may be employed. The smaller products consist of crushed stone of various sizes, stucco, terrazzo, and granite dust. The chief dimension-stone products are ashlar, rough building blocks, massive rectangular blocks for breakwaters, piers, etc., cut stone, monumental stone, columns, bases, sills, and various other structural members, paving stones, curbing, and flagging.

It seems logical to divide the quarries into these two groups, because their manufacturing and marketing problems are quite dissimilar. In quarrying broken stone heavy charges of explosives are used, the rock is loaded with power shovels and passed through crushers and over screens, and the products are sold chiefly for road construction, railroad ballast, or concrete aggregate. In dimension-stone quarries explosives are used very sparingly, the rock masses are shaped to definite forms and sizes, and the rock surfaces may be finished by some special process such as tooling or polishing. A few dimension-stone quarry operators, however, manufacture crushed-stone products from quarry or mill waste, and such manufacturers are of course interested in the problems of both groups.

This paper is confined to consideration of the dimension-stone group only.

USES

Granite quarries for the production of dimension stone may be divided into three groups: (1) Those producing paving blocks and curbing, (2) those producing structural building stone, and (3) those that produce monumental stone. While curbing and paving production is a somewhat independent and distinct branch the other branches blend into each other to some extent. Monuments or tombstones may consist of single blocks or of two or more blocks, such as bases and dies, or the monumental stone may be used for the construction of large and elaborate mausoleums, thus really becoming part of the building-stone industry. On the other hand, granite used in buildings, while consisting chiefly of unpolished cut stone, includes also polished columns, polished base courses, baseboards, and interior or exterior decorative units manufactured in the same way and with the same surface finish as monumental granite.

DISTRIBUTION OF GRANITES IN THE UNITED STATES

Granites are quarried in block form in many parts of the United States. From the standpoint of general distribution granites occur in four chief areas, as follows: (1) The Appalachian district of eastern United States from Maine to Georgia; (2) the Middle Western States, particularly Minnesota and Wisconsin; (3) the Rocky Mountain States, the deposits of which have not been developed extensively; and (4) the Pacific Coast States, particularly California. Granite is also produced in more or less isolated areas in other States outside these four main territories.

The total values of the various types of dimension stone sold in the United States in 1928 are as follows: Monumental, $11,217,229; building, $7,671,013; paving blocks, $2,934,604; curbing, $2,607,152; rubble, $321,442. The leading centers of production of monumental granite are Barre, Vt., Quincy, Mass., and St. Cloud, Minn. The 10 leading States in order of production value of monumental stone in 1928 were: Vermont, Minnesota, Wisconsin, Massachusetts, California, Georgia, Rhode Island, North Carolina, New Hampshire, and Maine. These States together produce about 86 per cent of the total. The 10 leading

States in order of production value of building stone in 1928 were: Massachusetts, Minnesota, North Carolina, New York, New Hampshire, Maine, Georgia, Maryland, Pennsylvania, and Vermont.

The production of granite in tons and value by States, together with other statistical information, has been published by the Bureau of Mines in a report entitled, "Stone in 1928," a copy of which may be obtained from the Superintendent of Documents, Washington, D.C. for 10 cents. Such reports are issued annually.

DESIRABLE QUALITIES OF A DEPOSIT

Granites are of very wide occurrence in many countries of the world. Single masses, as indicated by numerous related outcrops, may extend over thousands of square miles. Relatively few of these occurrences, however, have the qualities, locations, or working conditions requisite to adapt them to industrial uses.

The quality of the rock itself is of first importance. An even-grained uniform texture, together with a uniform and attractive color, is desirable. Uniformity in texture is commonly marred by the presence of undesirable streaks or spots. Such defects may consist of "black knots," which are of two types: (1) Segregations of dark-colored minerals, such as mica or hornblende, into spots or streaks, and (2) inclusions of dark-colored rock fragments. Narrow diabase or "trap" dikes may appear as dark bands across the granite, and "aplite," a fine-grained light-colored granite, may form white dikes. The presence of dikes of either kind usually condemns the rock for structural or ornamental uses. Fine black or green lines, known as "hair lines," appear in some granites. Any of these structures, except possibly the dikes, are permissible in granite used for paving blocks, curbing, and unpolished building blocks. For the more ornamental uses employing polished granite, rock having such defects must be avoided, for the imperfections will appear on the polished surface like blots or streaks on a sheet of paper.

Most granite masses are intersected by cracks or joints, usually approaching a vertical direction. The most favorable condition is one in which the joints are spaced several feet apart and are in two systems, approximately at right angles to each other. If the joints are closely spaced or irregular, blocks of adequate size may be unobtainable or the waste may be excessive.

The depth of overburden is an important factor. The presence of 30 or more feet of soil over the rock adds considerably to the quarry expense. A bare outcrop is usually regarded as most favorable, for there is no expense for soil removal. However, the protection of several feet of soil is sometimes found to be advantageous. Although granites usually resist weathering remarkably well the weathering effects of many centuries on exposed outcrops may bleach the color or cause some disintegration to a depth of several feet. This upper layer of defective rock must be removed as waste, and its removal is much more costly than the removal of an equal volume of soil. It has been found in some places that the protection of 5 to 10 feet of soil has so preserved the rock that it may be used for building purposes almost to the surface.

Drainage conditions must be observed carefully. The shelf or side-hill quarry providing automatic drainage is most desirable. On the other hand, a pit quarry demands pumping expense.

ECONOMIC CONDITIONS

Many granites of high quality and in localities where quarrying conditions are favorable are unused because they are too remote from profitable markets or have unfavorable transportation or power facilities. The high-priced, ornamental rock has a much wider market range than the lower-priced, unpolished building granites. The success of a monumental granite enterprise depends to a large extent on its ability to meet popular demands in color and texture.

QUARRY METHODS

Stripping is the first step in opening up a granite quarry. There are many different methods of removing overburden, and the choice is governed largely by quarry conditions. If several feet of clay, sand, or gravel must be removed mechanical means should be employed if possible. Power shovels, drag-line scrapers, or excavators may be used. Hydraulic stripping is the cheapest but can be used only where conditions are favorable, the chief requirements being adequate water supply and a favorable drainage direction to a waste-disposal area. If the surface rock is inferior it may be removed by blasting; but heavy charges should not be employed, as the underlying serviceable rock may be shattered.

Drilling may be done with various types of equipment. Tripod piston drills are not as widely used as in former years, being displaced by hammer drills which are more quickly moved and more easily handled. In some quarries tripod piston drills are used for the deeper holes and hammer drills for the smaller shallow holes, such as those used in plug and feather wedging. Power is supplied chiefly by compressed air, although steam is also used. Granite is a hard rock, and the tempering and shaping of drills require skill and care.

The larger masses may be separated from the solid ledge by blasting, light charges of black blasting powder being used. The charge should be sufficient to make a fracture without shattering the mass. Primary fractures are made in directions of easy splitting, known as the rift or grain, which are more fully described in a following paragraph. If blasting seems undesirable a cut is sometimes made by drilling a row of closely-spaced holes and by broaching out the narrow webs between them.

Considerable saving in quarrying expense may be accomplished by utilizing joint seams to the best advantage. Though they are sometimes quite irregular there is a tendency for joints to occur in parallel systems. Commonly the more prominent joints appear as a major system. A secondary or minor system may intersect them, and it is highly desirable that the two systems should intersect at angles approaching 90°. By utilizing joints in the removal of rock masses the sides of the quarry opening will automatically parallel the two jointing systems. Medium-spaced joints are the most advantageous; if too closely spaced, small blocks only are obtainable; if far apart, the cost of quarrying will be relatively high.

In opening up a new bench on a quarry floor the most difficult step is to obtain a free face from which to work. A mass of rock 3 to 5 feet wide and the depth of the bench must be removed to give the necessary working space. Different methods are employed to make such a trench. If the mass is flanked on either side by an open seam it may be removed by drilling and blasting. If open seams can not be utilized thus, holes may be drilled in two parallel rows 3 to 5 feet apart and the intervening rock shattered with dynamite and removed as waste. Another method is to drill the holes close together and to remove the thin walls or webs between them with a flat broaching tool, thus forming a narrow channel. Two such channels may be made, parallel with each other and any desired distance apart. When the rock between them is removed a trench is provided. This method is less wasteful than blasting, for the mass of rock between the channel cuts may be removed in block form and utilized. In some quarries it is found advantageous to use the channeling method for many subsequent cuts. Although it is more costly than blasting the waste reduction is more than sufficient to compensate for the additional cost.

Natural partings in granite which are either horizontal or roughly parallel with the rock surface are known as sheeting planes. If present, they greatly facilitate quarrying; if absent, artificial breaks must be made by blasting or by other means. In certain North Carolina and Georgia granites, where few or no joints or sheeting planes are present, artificial sheeting planes are started with light charges of black blasting powder and completed with compressed air.

When the larger masses are separated from the solid ledge the next step is to subdivide them into blocks of the approximate sizes and shapes desired in the finished product, or into convenient sizes for removal from the quarry. In this process the natural splitting tendencies of the rock must be taken into account. Most granites exhibit a tendency to split with greater ease in certain directions than in others. Usually there are two directions of easy splitting approximately at right angles to each other, one of them being more pronounced than the other. The easier direction of splitting is termed the "rift." The second direction of splitting is termed the "run" in some localities and the "grain" in others. In the third direction, which is approximately at right angles to both rift and run, the rock splits with the greatest difficulty, and this direction is termed the "hard way."

To obtain the easiest splitting and the smoothest surfaces the major fractures are made in the directions of rift or grain. Hand-operated compressed-air drills of the hammer type are generally employed to make a row of drill holes along the line where a break is desired. The holes may be only 3 to 6 inches deep and 1 or 2 feet apart. The break is made by driving "plug-and-feather" wedges in the holes. The "feathers" consist of two split wedges of steel or iron that fit into the drill hole, and the "plug" is a steel wedge or tapered bar which is driven between them.

Derricks are usually employed for hoisting the rough blocks to the quarry bank. In wide and shallow quarries, such as are found in North Carolina and Georgia, blocks are removed partly with caterpillar or other tractors and partly with mule carts.

FINISHING METHODS

Rough blocks taken from the quarry may be subdivided further to desired shapes and sizes by driving plug-and-feather wedges in shallow drill holes. Rough and uneven ends may be slabbed off in this way.

Saws have been employed occasionally for many years, but only during recent years have they been used widely in granite mills. Many mills are now equipped with gang or circular saws using an abrasive, such as steel shot. A gang saw consists of a series of soft steel blades attached to a frame. When a block of granite is placed beneath the gang, a backward and forward motion of the blades will make a number of parallel cuts at the same time. The circular saw makes a single cut but advances more rapidly than the gang saw. Other forms of saws are also in use.

As the mineral constituents of granite are very hard, sawing is a slow and costly process. It is employed, therefore, only for the more expensive types of ornamental granite.

Though it is expensive, sawing has certain definite advantages. Thin slabs of granite, which could not be profitably shaped in any other way, are easily obtained by sawing. Furthermore, the most attractive surface on some granites is parallel with the "hard way," the direction in which the rock splits with difficulty, and with a rough surface. By ordinary methods of splitting with wedges it is almost impossible to obtain blocks having their larger surfaces parallel with the "hard way;" but by the sawing method, surfaces parallel with this direction are obtained just as easily as those in any other direction. Sawing also conserves the rock by reducing waste.

Where rough quarry blocks are dressed into building blocks without sawing the first step in manufacture is termed "lining," which consists in working the edges of the block to the required dimensions. This is usually done with pneumatic chisels. The next step, known as "pointing" or "surfacing," is to dress down the faces to the edge dimensions. Hand pointing is done either with a chisel and mallet or with a pneumatic tool. Machine pointing is done with "surfacing machines." Essentially the machine consists of a steel tool with blunt projections which is given a rapid reciprocating motion. As it travels over the surface it chips off fragments of rock, gradually working it down to an even surface. A heavy tool is used to remove the larger irregularities, and a lighter tool with smaller projections may be used to give a tooled-surface finish. The free face is commonly provided with a rough rock-cleft surface.

If a polished surface is desired the blocks from the surfacing machine are placed in groups of 8 or 10 on a timber bed with their upper surfaces on an even plane. The rectangular group of blocks is surrounded by a wooden box, the bottom of which is a little lower than the rock surface. All cracks in the box and between the blocks are filled with plaster of Paris. Coarse steel shot is placed on the rock, and a stream of water is directed on the surface. A belt-driven revolving head is guided over the blocks, and the shot coming between the rotating head and the rock gradually wears down the surface. Fine shot, emery, or carborundum powder, are employed successively, care being taken to wash out all fragments of a coarse abrasive before a finer one is employed. Final polishing is done with "putty powder," which consists chiefly of tin oxide. If more than one surface of a block is to be polished it is turned and reset in another bed. Hand rubbing may be required to finish edges and corners.

Some shops are equipped with turning lathes for turning down and polishing granite columns. Carborundum wheels are now employed in various ways in granite mills, but the cutting must be done very slowly and carefully and with an abundance of water. Carving and lettering may be done with hand chisel and mallet or with compressed-air-operated tools, and sand blasting also may be employed. Modern granite mills are well lighted, heated, and ventilated and are provided with suction fans for removing the granite dust from the machines and tools.

Waste blocks are sometimes sold for rough building purposes. Both mill and quarry waste may be crushed and sold for road building, for railroad ballast, or for concrete aggregate.

Some companies quarry only, selling their rough blocks to the finishing mills. Other companies operate both quarries and mills, selling their finished products to retail monument dealers or supplying stone to builders or contractors. A third group operates mills only, buying their rough stock from quarry operators.

MONUMENTAL AND BUILDING GRANITES

Monumental granites

The highest grade of granite produced is stock suitable for polishing for the manufacture of monument dies or for other decorative uses. The blocks are carefully selected on the basis of color, texture, and freedom from defects, for they must be attractive enough to meet popular demands and must be free from blemishes. As many of them fail to pass inspection and are rejected the quarry cost is high.

Finished monuments from the Barre, (Vt.) district are the most widely distributed of all granites, finding a market in practically every State. Quincy, (Mass.) granites are also widely used. Granite monuments from St. Cloud, Minn., and from Wisconsin are marketed chiefly in the Middle West, though they are used to some extent in more distant States. Vermont and Massachusetts granites are gray, most of the Rhode Island and Connecticut granites are light pink, and the chief products of Minnesota and Wisconsin are red in color. The so-called black granites of Pennsylvania and New Jersey find a market in New York, N. Y.

Building Granites

Building granite is sold in the form of dressed blocks having shapes and sizes specified by architects or in roughly shaped blocks suitable for ordinary building purposes. The rock must be of good color and quality, but many of the minor defects not permissible in monumental stone may be allowed in building stone. In general, therefore, the selection is less rigid for building than for monumental stone, and the production cost is relatively lower. Large quantities of building granite are produced in New England, particularly along the Atlantic Coast, also in eastern Pennsylvania, North Carolina, Georgia, and California. It is used for entire structures or for base courses and trim in residences, office buildings, stores, banks, churches, and other public buildings, while a very important application is in bridge construction.

STATISTICS OF PRODUCTION

The following table gives the amount and value of the various types of granite sold as dimension stone in the United States during the years 1919 to 1928.

Amount and Value of Dimension Granite Sold in the United States, 1919 to 1928 Inclusive

	Building Stone		Monumental Stone		Paving Stones		Curbing and Flagging		Rubble		
Year	Cubic feet	Value	Cubic feet	Value	Number	Value	Linear feet	Value	Short tons	Value	Value (total)
1919	3,651,200	$2,267,875	3,658,422	$10,143,313	33,601,520	$2,369,521	822,967	$641,726	97,635	$140,694	$15,563,129
1920	4,895,880	4,492,482	3,379,330	11,543,255	32,230,270	2,582,934	997,950	755,540	90,760	154,036	19,528,147
1921	4,051,650	4,206,346	1,956,720	7,253,276	37,201,360	3,222,007	1,171,990	857,799	182,730	219,129	15,764,557
1922	5,058,320	4,247,131	2,085,740	7,429,332	25,693,300	2,232,628	1,407,760	900,101	174,740	221,264	15,030,456
1923	5,244,250	5,011,362	3,947,600	12,398,457	41,016,640	3,578,182	2,104,150	1,436,212	167,980	183,589	22,607.802
1924	6,844,550	5,663,776	3,520,530	11,447,196	37,599,100	3,284,395	2,251 760	1,513,137	235,150	243,156	22,151,660
1925	7,515,400	6,814,577	3,195,290	10,805,432	37,674,930	3,485,714	2,779,570	1,839,830	270,410	328,379	23,273,932
1926	8,181,910	6,883,513	3,240,550	10,533,072	37,148,000	3,223,327	3,503,370	2,402,284	121,910	182,306	23,224,502
1927	6,397,830	7,672,112	3,197,910	10,881,442	35,949,790	3,368,178	3,431,290	2,605,478	484,770	426,587	24,953,797
1928	6,704,430	7,671,013	3,172,730	11,217,229	32,949,300	2,934,604	3,548,220	2,607,152	310,720	321,442	24,752,539

1 - Compiled from Mineral Resources Reports of the U. S. Bureau of Mines.

IMPORTS AND EXPORTS

The following table gives the imports of granite for consumption in the United States during recent years.

Granite Imported for Consumption in the United States, 1919 - 1928

Year	Dressed, value	ROUGH		Value (total)
		Cubic feet	Value	
1919	$9,983	23,240	$17,796	$27,779
1920	108,193	43,805	42,162	150,355
1921	108,219	32,525	27,258	135,477
1922	183,776	72,061	106,121	289,897
1923	270,432	176,096	221,796	492,228
1924	302,927	196,176	255,225	558,152
1925	359,364	213,594	273,298	632,662
1926	324,794	235,176	287,116	611,910
1927	319,644	188,395	257,470	577,114
1928	244,043	178,427	272,428	516,471

About 60 per cent of the imports of unmanufactured monumental granite is obtained from Sweden. The Swedish granites are chiefly dark, the so-called black granites. Red granite from Finland is second in importance. Imports of monumental base stock and building granite come chiefly from Canada.

Imported manufactured granite consists largely of monument dies with polished surfaces. The chief imports are from Germany and consist of dies manufactured from red Swedish granite. Finland is second in importance as a foreign source of supply. The imported manufactured granite is purchased chiefly by wholesale dealers in Ohio, and most of it is sold to retail monument dealers west of the Alleghanies.

According to the tariff classification granite exports are combined with exports of a number of other commodities, and therefore can not be shown separately, but the amount is small.

RATES OF DUTY

The Tariff Act of 1922, paragraph 235, provides that monumental granites, hewn, dressed, polished, or otherwise manufactured shall be subject to a duty of 50 per cent ad valorem, and that unmanufactured granite shall be dutiable at 15 cents per cubic foot.

PRICES

Granite for building purposes is usually sold on contract. In random blocks without cutting or carving it is quoted at prices ranging from $1.40 to $2.25 per cubic foot at points of consumption. Unmanufactured monumental granite varies in price from $3 to $4.50 per cubic foot, f.o.b. quarry.

Granite paving blocks, grade 1 (30 blocks per square yard), are quoted at about $150 per thousand delivered. Granite curbing is usually sold by the linear foot, straight curbing averaging about 80 cents a foot f.o.b. quarry. Curved curbing is somewhat higher in price. In certain localities curbing prices vary greatly from the average. For example, a recent New York quotation is $3.37 per linear foot for corners and $2.25 for straight, but this is a delivered price, including both rail or water haul and trucking.